SHORTER CONTRIBUTION

A study of the wavelength exponent of aerosol scattering using Volz sunphotometer

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Introduction

In a recent paper, Rangarajan (1972) has reported measurements of atmospheric turbidity made for a period of one year at Poona (18°32′ N, 73°51′ E, 555 m a.s.l.) using a sunphotometer. Turbidity parameters were computed from measurement of direct solar radiation at two wavelengths 0.4 μ and 0.6 μ using interference filters with a half width of 30 Å and 20 Å respectively. The main feature of his study was that the value of the turbidity parameter α (the wavelength exponent of aerosol scattering in the expression for the decadic turbidity coefficient due to aerosols. $a_\lambda = B\lambda^{-\alpha}$, B being a parameter characterizing the total amount of aerosol in a vertical column) was consistently lower than the classical value of 1.3 suggested by Ångström (1964) for temperate latitudes. Rangarajan has suggested, based on his data, a value of 0.5 for α to be used for tropical latitudes. The low value of α obtained by him has elicited discussion in this journal (Ångström, 1972; Rangarajan, 1974) bringing to focus the fact that the determination of α can be very sensitive to instrumental errors in the measurement of solar radiation. In this note, we present some preliminary results of Volz sunphotometer observations for a period of three months (10 December 1974 to 20 March 1975 during which clear days are frequent) at this research centre in Bombay (19°1′ N, 72°55′ E, 30 m a.s.l.) and discuss the values of α obtained during the course of this study.

Measurement of solar radiation

Direct solar radiation measurements (within 2° field of view) were made using a Volz sunphotometer (for a full description of the instrument see a recent paper by Volz (1974)) having interference filters centred at 0.5 μ, 0.88 μ and 0.94 μ and a half width of about 3% of the peak wavelength. The wavelength 0.94 μ corresponds to $\varrho\sigma\tau$ absorption band of water vapour while 0.88 μ corresponds to the adjacent window region. Measurements made at 0.5 μ and 0.88 μ are used in this study to evaluate α and the decadic turbidity coefficients $a_{0.5\mu}$ and $a_{0.88\mu}$. The photometer uses a silicon photovoltaic cell which is more stable, has a linear response (non-linearity less than 1% over full scale) and very low temperature drift in comparison to selenium cells used in some of the earlier sunphotometers (e.g. Rangarajan, 1972). No amplification of the output from the sensor was, in general, found necessary during the course of observation for optical air masses below 6; whenever measurements were made at larger air masses or highly turbid atmosphere, the photometer was coupled to a solid-state amplifier with suitable gain adjustment. Values of optical air masses at the time of measurements were computed from the solar elevation. In order to eliminate possible observational errors during periods of large optical air masses, the data used in this study were restricted to air masses ranging from 1 to 7. The Rayleigh and Ozone extinction coefficient assumed at 0.5 μ were 0.063 and 0.004 respectively while at 0.88 μ only Rayleigh extinction of 0.0064 was assumed.

Results and discussion

In Fig. 1 variation of 10 day averages of $a_{0.5\mu}$, $a_{0.88\mu}$ and α during the period of observation are shown. The following two features are evident from the figure:

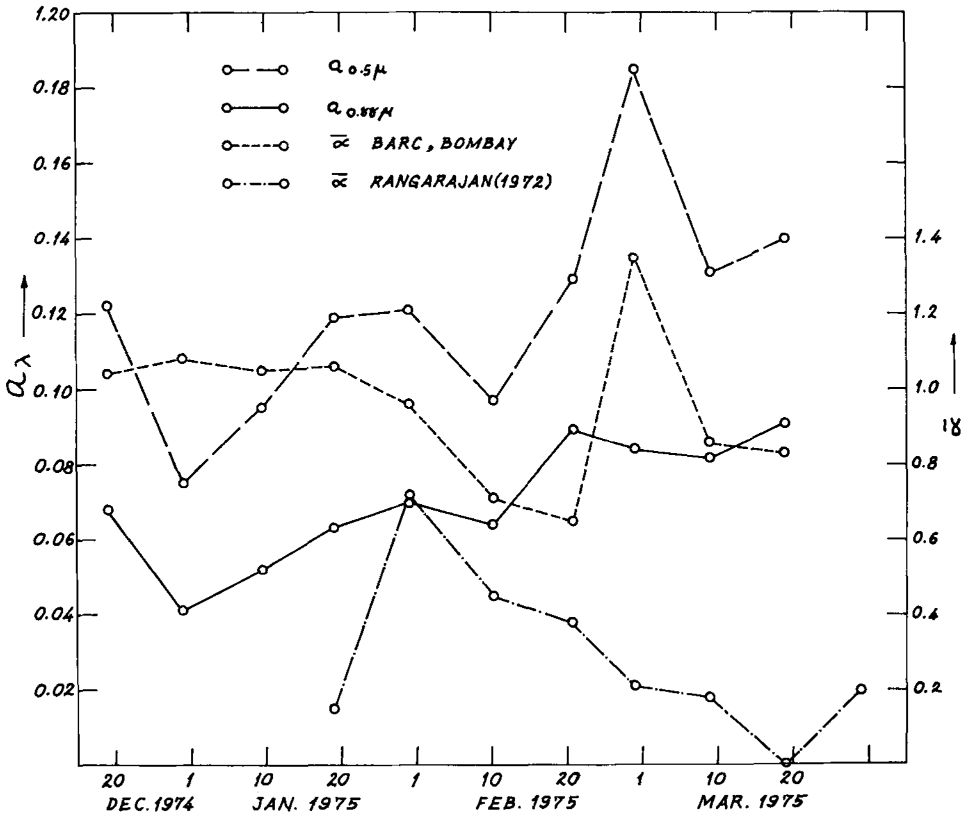

Fig. 1. Monthly variation of $a_{0.5\mu}$, $a_{0.88\mu}$ and α. Points represent 10-day average values.

(i) Though the values show wide fluctuations, turbidity has a definite increasing trend from December to March.

(ii) α has a mean value of 1.0 with a range from 0.6 to 1.3 but a trend is not apparent.

It is interesting to note the consistently high values of α observed in this study in contrast to the values reported by Rangarajan (1972) (also plotted in Fig. 1 for comparison). The frequency distribution of α values derived from individual pairs of observations are shown in Fig. 2*a* in the form of a histogram. The distribution is skewed with a median and mode of 1.0 and 1.1 respectively. There is a secondary mode at 0.7. Fig. 2*b* shows similar histograms for sun in eastern (morning) and western (evening) part of the sky. It may be noted that the secondary peak shifts towards lower α values in the western sector. Total number of cases less than $\alpha = 0.6$ are also less in the morning. This may be explained by the existence of the industrial area of Bombay lying to the west of the point of observation as a result of which the α values tend to be smaller.

An interesting feature of the observation is the characteristic diurnal variation of α obtained frequently during February and March when wet haze and mild ground level fog was present during morning hours under conditions of high humidity. Fig. 3 shows such a variation for a typical day (17 February 1975) where the individual values of $a_{0.5\mu}$, $a_{0.88\mu}$ and α are plotted. For reference, the diurnal variation of relative humidity is also shown in the figure. It could be seen that during morning hours with wet haze present due to high humidity, α values tend to be lower than that during midday when with the drop in relative humidity dry haze sets in. Such a negative correlation between α and relative humidity has been observed earlier (for e.g. Knestrick et al., 1962) under conditions of high relative humidity. On the contrary, Ran-

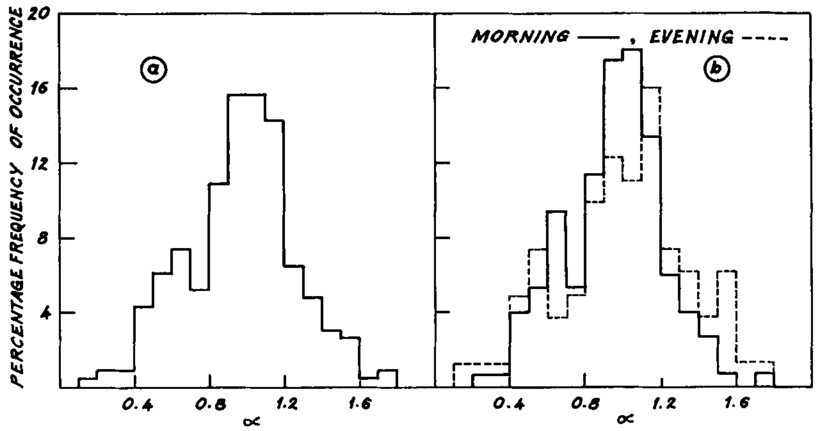

Fig. 2. Frequency distribution of α.

garajan (Fig. 6 of his paper (1972)) observes high value of α during morning hours which he attributes to wet haze. The reason for this is not clear since under conditions of high humidity, there is a predominance of large and giant aerosol particles tending to lower the value of α as observed in this study. The diurnal variation of α was not always so marked as cited in the above example; presumably the effect of humidity is only one of the factors affecting the value of α.

The α values reported for Bombay in this study are significantly different from those of Rangarajan (1972) for Poona which is only 150 km inland from Bombay. It would therefore be instructive to do an error analysis of the meas-

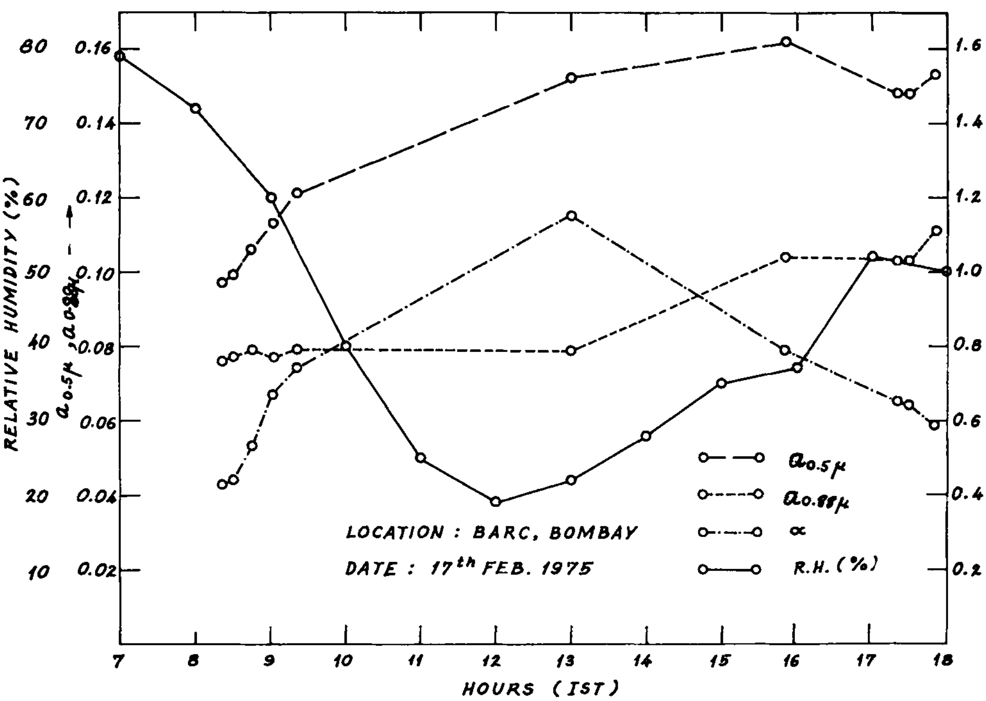

Fig. 3. Hourly variation of $a_{0.5\mu}$, $a_{0.88\mu}$, α and relative humidity.

urements. Laulainen (1974) has shown that imprecise estimate of the extra-terrestrial constant of the instrument is the most serious error in Volz sunphotometry. In our study, the original value of the extra-terrestrial constant supplied with the photometer was rechecked on a few occasions under conditions of uniform turbidity using the Langley method. It was found that the constant could show a variation as high as 5% in the 0.5 μ channel and 3% in the 0.88 μ channel. In order to reduce the effect of this error on turbidity and α values, majority of the observations ($\sim$60%) were made during periods of optical air mass from 3 to 7 (in contrast to less than 3.5 in Rangarajan's measurements). If we assume an average optical air mass of 4, the error in individual values of $a_{0.5\mu}$ and $a_{0.88\mu}$ would be between 5 and 10% for the limits corresponding to clear and very turbid sky respectively. With the type of atmosphere invariably found over Bombay, a pessimistic estimate of the error in α would be 20–30%. Even allowing for such an error, the α values obtained in this study are higher than those obtained by Rangarajan, for which an error analysis is not available. However use of low air masses can lead to proportionately higher errors in a_λ and even higher errors in α. Considiering the errors, the value of $\alpha = 1.0$ for Bombay reported in this work is more in agreement with the mean value obtained by Anna Mani et al. (1969) from pyrheliometer measurements made at a net work of weather stations.

Acknowledgements

Thanks are due to Shri S. D. Soman for his constant encouragement throughout the course of this study.

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